Engineering Tripos Part IA, 1P3: Physical Principles of Electronics and Electromagnetics, 2019-20

Course Leader

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Lecturer

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Timing and Structure

Weeks 1-3, Michaelmas term & weeks 4-6 Lent term,12 lectures, 2 lectures/week in two separate parts. Part 1 - 6 Lectures: Physical principles of electronics, Part 2 - 6 Lectures: Electromagnetics

Aims

The aims of the course are to:

- Develop an understanding of electromagnetic fields and their application to the solution of a range of engineering problems, building directly on the knowledge students have gained at A-level.

Objectives

As specific objectives, by the end of the course students should be able to:

- Understand the physical properties that lead to resistance, capacitance and inductance.
- Analyse simple geometries used in these components
- Understand the basic laws of electromagnetism, Gauss, Ampere, the method of images, virtual work etc.
- Calculate the electric and magnetic fields produced by simple charge and current distributions.
- Develop an understanding of the relation between field and circuit concepts
- Calculate the capacitance, inductance, and mutual inductance for simple circuits.
- Understand how energy methods can be used to estimate electromagnetic forces.
- Design simple electromagnets and permanent magnets.

Content

The emphasis during the course will be on the physical understanding of the principles involved. Only elementary mathematical methods will be used, including basic vector concepts of superposition, dot product and cross product.

The overall course will cover three main areas through the two parts:(i) electrostatics: (ii) magnetic fields: and (iii) magnetic materials. Each part will contain a theoretical description of the concepts followed by applications to a range of problems of engineering interest.Part 1 is designed to introduce the physical properties of electromagnetics leading to the resistor, the capacitor and the inductor. This is done through a purely scalar theoretical analysis of the electromagnetic concepts. Part 2 takes the concepts of Part 1 and expands them on a more general sense to gain a more fundamental understanding of electromagnetic problem and materials. Throughout the course there will be an emphasis on the way approximation must be introduced when analysing engineering problems.

Part 1 Physical principle of electronics (6 Lectures) (6L)

- Physical principles - charge and charge accumulation
- Coulomb's Law - from force to an empirical derivation of electric field (and and
- Concept of electrical field (E) (with ref to point, line and surface)
- Dielectrics, idea of polarisation charges, dielectric breakdown
- The electric flux density (D) - simple geometries, point, line and surface
- Scalar definition of Gauss' law for a given surface, flux conservation
- Electrostatic potential and voltage - scalar calculation EdI
- capacitance, Q=CV, examples:(i) parallel plate capacitor (ii) coaxial line
- AC properties of capacitance (CdV/dt), simple definition of reactance (1/jwC)
- Charge flow - ohms law and current
- Simple derivation of current density (J)
- Simple description of resistance and resistivity
- Empirical definition of force between current carrying wires
- Ideas of magnetic flux density (B) from between wires
- Simple Biot Savart Law to give a circulating magnetic field
- Examples: (i) B field around a wire, (ii) B field from a loop of wire, (ii) field in a solenoid
- Scalar version of Ampere's law based on flux density circulating a wire
- Concept of Magnetic flux and flux linkage
- Faraday's Law of a electromagnetic induction
- Inductance, examples of coil and coaxial line, definition of mutual inductance
- AC properties of inductance (jwl)

Part 2- Electromagnetics (6L)

Electrostatic systems (3 lectures)

- Further symmetries - the method of images
- Vector definition of E-field and Gauss' Law
- Energy in a capacitor and electric field. Energy storage + effect of dielectrics
- Using virtual work to estimate forces (const voltage version) + examples

Magnetic systems and materials (3 Lectures)

- Need for magnetic materials
- Ideas of magnetic field (H) and the relative permeability
- Ampere's Law with linear, MMF, Vector form of Ampere's Law.
- Non-linear materials, saturation, magnetistion curve and hysteresis, transformers?.
- Permanent magnets.
- Energy and forces in magnetics circuits - virtual work example.
- Magnetics energy as integral of HdB
- Estimating forces between magnetics materials (EM and permanent)

Booklists

Please see the Booklist for Part IA Courses [2] for module references

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

E4

Understanding of and ability to apply a systems approach to engineering problems.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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